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Environmental rehabilitation of mining dumps

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Abstract

Mining exploitations, especially the surface ones, severely degrade the environment by removing large areas from agricultural and forestry use, micromorphological changes, hydrogeological and hydrographic changes, air, water and soil pollution, flora and fauna losses, microclimate changes, historical and archaeological sites damages, displacements of settlements and transport routes. Results obtained following the agrochemical experiments show that increasing the doses of fertilizers had positive effect on yields of all the tested crops.

This paper presents several experimental fertilizers: four liquid fertilizers associating humic substances extracted from lignite with a complex matrix containing macronutrients (nitrogen, phosphorus, and potassium) and trace elements (copper, zinc, iron, manganous, boron); two types of organo-mineral fertilizers with macronutrients on a lignite carrier; two types of organic fertilizers (containing cattle manure or compost obtained from cattle manure, lignite powder and potassium humates). These experimental fertilizers were tested - alone or associated with mineral fertilizers - on maize, sunflower and peas crops.

In all three experimental years, and for all three crops, the best yields were obtained for the variants fertilized with 40 t/ha compost + $N_{100}P_{80}K_{80}$. Thus, a 364% average yield increases were recorded for maize, 310% for sunflower and 156% for peas crop, compared to the control plot (unfertilized). For maize crop, the following yield increases have been recorded, comparing to the control plot: 165% for mineral fertilization ($N_{100}P_{80}K_{8}0$); 253% for the variant with 40 t/ha cattle manure; 277% for the variant with 40 t/ha cattle manure + $N_{100}P_{80}K_{80}$; while the variant with 40 t/ha compost led to a 256% yield increase. Regarding the variants with organo-mineral fertilizers, yield increases between 196% and 229% were obtained, as compared to the control plot. Liquid fertilizers with humic substances extracted from lignite highlighted very significant yield increases (135-158%). Similar observations were recorded for sunflower and peas crops.

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Keywords: recultivation; sterile dump; mineral and organic fertilizers; liquid fertilizers; humic substances.

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1. Introduction

In the mining areas in Oltenia (Dolj, Gorj, Valcea, Mehedinti) 18443 ha were withdrawn from economic cycle, of which 13680 ha of agricultural land and 4763 hectares forest land, and by the end of the exploitation works will affect 26476 ha, of which 15490 ha agricultural lands and 10982 ha forest land (Cărăbiş, 2013).

The mining industry seriously affects the environment through: degradation of large areas of farmland and forestry lands, geomorphological changes, hydrogeological and hydrographical changes, water and air pollution, losses of flora and fauna, microclimate changes, dislocations of human settlements and communication routes, losses of historical and archaeological sites; impairment of social inhabitants (Munteanu, 1998; Ianc, 1999; Akala and Lal, 1999; Dumitru et al., 1999; Daniels et al., 1999; Corici, 2006; Pascovici, 2006, Dinucă and Târziu, 2015).

Serious environmental effects have imposed the development of research to combat these effects, for the rehabilitation of the affected areas.

Large affected areas led to the development of technologies for re-cultivation. Re-cultivation process comprises two distinct phases:

- Mining recultivation stage, to be carried out by the company which produced degradation. At this stage the following activites are done: selection operation, dumps selective arrangement, erosion prevention measures, levelment, creating access roads, etc.
- Biological recultivation stage, which is designed to increase fertility for dump materials, including amelioration measures, as well as specific crop technologies for dumps.

Re-cultivation has its own specific character for each area to be drawn into the economic circuit. The most important directions for the enhancement of degraded lands are as follows:

- Agricultural re-cultivation, which aims to cultivate these dumps with grain crops, fruit trees, vineyards, pastures and meadows, etc.
- Forestry re-cultivation, i.e. the establishment of forests with commercial or protection role, in order to restore the soil, biodiversity, hydrological regime, aesthetic and recreational function, climate, for fixing CO_2, oxygen production, water quality improvement, retaining pollutants, etc.;
- Sanitary-hygienic re-cultivation purposes, i.e. recreational areas, parks, grassing for environment protection, golf sport fields, tourist areas, etc.
- Build lakes with different purposes: reservoirs, lakes fisheries, lakes with regulatory role for hydrological regime, sport areas, etc.
- Re-cultivation in order to improve habitat for wildlife, enhancing the conditions for hunting and fishing, restoring biodiversity, etc.
- Arrangement of industrial sites and housing, etc.

Choosing the crops structure and fertilization system is of great importance in the efficiency of ecological rehabilitation of degraded lands by opencast mining, looking for to obtain agricultural yields similar to those achieved on neighbouring un-degraded lands in similar conditions of economic efficiency (Dumitru et al., 1999; Bendfeldt et al., 1999; Daniels et al., 1995; Tatomir et al., 2010; Mocanu et al., 2007; Dumitru et al., 2008; Călinoiu, 2013; Băbeanu, 1998; Becheriţiu, 2003; Blaga, 1981; Eger et al., 1999; Braia, 2004; Călinoiu, 1999; Cătinaş, 2012, Clapa, 2003, Craioveanu et al, 2002; Chisăliţă, 2001; Călin, 2012; Dinucă, 2015; Ianc, 1999; Munteanu, 1998; Negrea, 2007; Oprea, 2010; Pascovici, 2006; Popa, 2007; Roşculete, 2005).

The main features of materials from dumps which affects the production are as following: excessive texture (too sandy or too clayey), the excessive skeletal content, low content of humus, low contents of nitrogen, phosphorus, potassium, micronutrients, poor aero-hydric regime, reduced biological activity.

The presence of coal residues leads to better conditions for re-cultivation dumps. Charcoal from dumps consists of two parts: one part that can not be mineralized or is very slow mineralized, represented by derivatives of lignin and aromatic nucleus with a high degree of polymerization and from a mineralized part, represented by humic substances which, by microbial decomposition, can provide nitrogen for plants and soil microorganisms (Becherescu et al., 2008). The values of organic carbon content obtained by analysis from soil humus and that from coal are often misaddressed, despite they are different used by plants. Therefore, even dumps have high levels of organic carbon, they often have a low potential for crop production and require large doses of organic, organo-mineral or mineral fertilizers to achieve reasonable yields. The low level of nutrients in soluble form in the substrate

leads to increasing yields with increasing fertilizer rates and to very low yields increases per kilogram of active applied ingredient.

Organic fertilization with manure, compost, green manure or crop residues must be accompanied by mineral NPK fertilization. Organo-mineral fertilizers with lignite having humic acids associated with various minerals provide deficitary elements for plant nutrition and also improve soil quality for soils with low humus content. The humic substances are the main factor in cementing and agglutinating and forming micro and macro aggregates, leading to increased porosity and water storage capacity. Structured soil is more easily penetrated by roots in contact with surfaces of microaggregates, creating better conditions for nutrition (Dorneanu et al., 2008; Eyheraguibel et al., 2008).

2. Materials and Methods

On the Balta Unchiașului dump from Rovinari, uncovered with fertile soil, an experiment was placed, in four repetitions, for different crops: maize (H300 Fundulea hybrid), sunflower (Fundulea 206 variety), and peas (Vedea variety). The experiment had 10 variants, consisting of mineral fertilizers ($N_{100}P_{80}K_{80}$), organic fertilizers (40 t/ha manure from cattle and 40 t/ha compost, obtained from manure, lignite and humic acids extracted from lignite, associated or no with mineral fertilizers) and organo-mineral fertilizers on lignite support L200 and SH210 in doses of 1000 to 1500 kg/ha).

The compost was developed based on the observation that cattle manure increased in household system provides very small production increases due to nitrogen deficiency, and the presence of coal residues from dumps significantly affects crop yields. Therefore, manure and lignite dust were mixed and compostated, and finally potassium humates were added, obtained by treating the lignite with potassium hydroxide.

The organo-mineral fertilizer L200 contains on average: 44% coal, at least 21% nitrogen, at least 16% humic acids, 0.255% potassium, 0.012% calcium, 0.188% magnesium 0.930% iron, 0.006% manganese, 0.027% zinc, and 0.017 % copper. The cation exchange capacity is 48 me/100 g, pH: 6.87, bulk density: 0.738 g/cm^3. The organo-mineral fertilizer is 82% present in the form of granules of 1-5 mm.

The organo-mineral fertilizer SH210 contains 40% coal, at least 17% humic acids, 20.55% total nitrogen, 9.75% phosphorus, 0.226% potassium, 0.011% calcium, 0.160% magnesium, 0.7955 iron, 0.005% manganese, 0.023% zinc, and 0.015% copper. Cation exchange capacity was of 41 me/100 g, pH of 6.30, bulk density of 0.720 g/cm^3. It is 80% presented in the form of granules of 1-5 mm.

The special value of the soils fertile horizon, characterized by the presence of its structure, a higher content of humus and nutrients, high biological and enzymatic activities produced by a variety of species of microorganisms, imposed regularly recommendation for exploitation, conservation and selective filing of this horizon. The essential condition for enhancing this horizon consists in complying the soil removing conditions, not stirring it with other horizons, storing in special dumps for as short a period of time and uniform tailings disposal, avoiding compaction. The ticknesses of soil cover of at least 30-40 cm are are done in Balta Unchiașului dump from Rovinari. Previous research has shown that even covering with fertile soil, the intense mineral and organic fertilization is crucial for yields closed to those from the zonal soils before degradation.

In the experiment organized in Balta Unchiașului dump, covered with topsoil, four fertilizers were tested for maize crop, based on liquid humates extracted from lignite in doses of 100 and 150 l/ha. The experiment included nine variants with four replications. The process for the preparation of tested liquid fertilizer was the neutralization of phosphoric acid 85% with potassium carbonate 98%, leading to a solution containing monopotassium and dipotassium phosphate, the reaction taking place under continuous agitation and at a temperature constant of 25-30ºC. During stirring the amide nitrogen source, nitrate and ammonia, is slow added, keeping constant the temperature of reaction, resulting in a complex mixture of macro-elements. In the complex solution of macro-elements a solution of trace elements (Fe, Cu, Zn, Mg, Mn, B) was added, chelated with EDTA disodium salt, and then a solution of potassium humate, obtained by extraction of the mass of coal (lignite), with a solution of potassium carbonate. The liquid fertilizer is applyied with 400-500 liters of water.

The compositions of AH and KH fertilizers are presented in Table 1.

Table 1. Compositions of AH and KH fertilizers.

Composition	"AH" FERTILIZANTS			
	AH - I	AH - U	AH - N	KH
	(g/l)			
Humic acids	20.5	20.5	15.5	9.35
Total nitrogen (N)	90	55	165	0.77
Phosphorous (P_2O_5)	35	50	30	1.73
Potassium (K_2O)	35	50	30	7.72
Bor	0.2	0.15	0.18	0.252
Cobalt	0.005	0.005	-	-
Cupru	0.1	0.15	0.2	0.2
Iron	0.25	0.3	0.4	0.2
Magneziu	0.1	0.15	0.4	0.263
Mangan	0.15	0.2	0.4	0.15
Molibden	0.005	0.005	-	-
SO_3	0.5	0.5	15	3.58
Zinc	0.1	0.15	0.2	0.192
EDTA	2.8	2.8	8.5	-
Total	**184.71**	**179.91**	**265.78**	**24.407**

3. Results and Discussions

Data obtained in the three years of experiment highlighted that the three crops (maize, sunflower and peas) used in Balta Unchiașului dump uncovered with fertile soil ensured very significant increases of yields after fertilization (Table 2). Therefore, the yields obtained on dump are closed to those obtained on the neighbouring agricultural lands, unaffected by mining.

The influences of the fertilization on the maize yields, as averages of three experimental years, are as following:

- Mineral fertilization with $N_{100}P_{80}K_{80}$ ensured a yield increase of 64% compared to unfertilized variant.
- Organic fertilization with 40 t/ha manure ensured a yield increase of 152%, and an increase of 156% compared to unfertilized;
- Organo-mineral fertilization with 1000 kg/ha L200 has led to a yield increase of 129%, while that with SH210 in an increase of 96% compared to the unfertilized;
- Organo-mineral fertilization with 1500 kg/ha L200 has led to an increase in production of 117%, while that with SH210 to an increase of 106%;
- The highest yield (3650 kg/ha) was obtained after fertilization with 40 t/ha compost plus $N_{100}P_{80}K_{80}$ offering a yield increase of 264% compared to unfertilized variant, an increase of 121% compared to mineral fertilization with $N_{100}P_{80}K_{80}$, a increase of 44% compared to organic fertilization with 40 t/ha manure, an increase of 42% compared to mineral fertilization with 40 t/ha compost, an increase of 58% compared to fertilization with 1000 kg/ha L200, an increase of 67% compared to fertilization with 1500 kg/ha to L200, an increase of 85% compared to fertilization with 1000 kg/ha SH210, and an increase of 77% compared to fertilization with 1500 kg/ha SH210.
- The best results are obtained by applying both organic and mineral fertilizers. Therefore, applying manure and mineral fertilizers lead to a yield increase of 177% compared to unfertilized variant, and 69% compared to mineral fertilization. While the application of compost with mineral fertilizers offered an increase of 42% compared to the compost fertilization.
- Among the advantages of using organo-mineral fertilizers, the followings are highlighted:
- Increasing the apparent use of nutrients from organo-mineral fertilizers comparing with those from mineral fertilizers mainly due to higher yield increases;
- Reducing nitrogen leaching by 25-36% compared to mineral fertilizers;
- Improving the soil humus content, due to the persistence of humic acids from coal (Dorneanu et al., 2008; Preda et al., 2008).

Similar effects of fertilisers were recorded for sunflower and peas crops (Table 2).

The yields levels achieved using fertilizers tested so far are still low compared to the capacities of zonal soils. This fact forced the use and test of liquid fertilizers based on humates extracted from lignite. These fluid fertilizers offer some advantages over the solid ones:

- Lower costs due to the elimination of evaporation and granulation stages and cheaper production equipment;
- Lower investment compared with facilities for solid fertilizers;
- Cheaper raw materials, lower quality;
- Fast, controlled and uniform incorporation in soil and high flexibility of the different elements balances;
- Superior physical qualities: not dusted, not crowded;
- Compatibility with fungicides, insecticides and trace elements. Their simultaneous application leads to better agricultural results than the solid fertilizers;
- Possibility to use together with irrigation water;
- Achieving a desired ratio between different species of ions and nutrients related to the crop and growth stage, agrofond, previously fertilization, with the opportunity to correct existing
- Catalyze soil reactions, accelerating chemical and microbial transformations at the root level, encouraging export increase of assimilated nutrients from the soil reserves;
- Mobilize nitrogen, phosphorus and potassium from the soil reserves;
- Simoultaneous introduction of several nutrients depending to the needs of technology, crop and soil;
- Large effectiveness for different crops, especially in the early stages of plant growth;
- They are not toxic, corrosive or pollutant, they are handled, dosed and applied in a simple, fast and efficient way by terrestrial or aerian methods or by irrigation systems;
- Decreases with 25-30% of the classic chemical fertilizers necessary;

They have a high degree of recovery of nutrients (Dorneanu, 2006; Sirbu et al., 2012; Cioroianu et al., 2009).

Table 2. Influence of mineral, organic and organo-mineral fertilizers on maize, sunflower and peas yields in Balta Unchiaşului dump, Rovinari.

Variant		Maize			Sunflower			Peas		
		kg/ha	%	Dif.	kg/ha	%	Dif.	kg/ha	%	Dif.
V1	Unfertilized	1003	100	-	607	100	-	620	100	-
V2	$N_{100}P_{80}K_{80}$	1650	165	647	767	126	160	765	123	145
V3	40 t/ha Manure	2533	253	1530	933	154	326	875	141	255
V4	40 t/ha Manure + $N_{100}P_{80}K_{80}$	2783	277	1780	1300	214	693	910	147	290
V5	40 t/ha Compost	2567	256	1564	1350	222	743	950	153	330
V6	40 t/ha Compost + $N_{100}P_{80}K_{80}$	3650	364	2647	1883	310	1276	970	156	350
V7	L200 (1000 kg/ha)	2300	229	1297	993	164	386	915	148	295
V8	L200 (1500 kg/ha)	2183	218	1180	1087	179	480	950	153	330
V9	SH210 (1000 kg/ha)	1968	196	965	977	161	370	1065	172	445
V10	SH210 (1500 kg/ha)	2063	206	1060	1090	180	483	980	158	360
DL 5%		144			154			50		
DL 1%		167			177			73		
DL0.1%		199			201			108		

Researches on Balta Unchiaşului dump covered with 30-40 cm fertile soil, for maize crop (Table 3) revealed the following:

- Application of 150 l/ha KH liquid fertilizer led to the highest maize yield, the very significant increase being of 183% compared to unfertilized variant. The application of 100 l/ha KH liquid fertilizer ensured a very significant yield increase (157%) comparing to the unfertilized variant;
- Fertilization with AH-I assured very significant yield increases of 130 and 149%;
- As regarding AH-U liquid fertilizer, only the dose of 100 l/ha led to very significant increases in maize yields compared to unfertilized variant; the 150 l/ha dose did not result in statistically increases of yields;
- Fertilizing with AH-N liquid fertilizer assured very significant increases of maize yields;
- The high yield level shows that the dump have created conditions for agricultural use of this land;
- The stalk of maize has to be chopped and incorporated into the soil with 10-15 kg nitrogen per ton of vegetal residues.

The very favourable effect of liquid fertilizers based on humates derived from lignite is mainly due to the presence of nitrogen in several forms: nitrate, ammonia, amide and to the split and localized application of fertilizer, highly reducing losses by leaching, and keeping a high concentration of soluble nitrogen in soil.

Table 3. Influence of liquid fertilizers based on humates on maize yields.

Fertilization system	Maize yield			Semnifi-cation
	kg/ha	Difference kg/ha	%	
Unfertilized	5480	-	100	
AH-I – 100 l/ha	7110	1630	130	***
AH-I – 150 l/ha	8160	2680	149	***
AH-U – 100 l/ha	7263	1783	133	***
AH-U – 150 l/ha	5797	317	106	
AH-N – 100 l/ha	9210	3730	168	***
AH-N – 150 l/ha	7700	2220	141	***
KH – 100 l/ha	8630	3150	157	***
KH – 150 l/ha	10030	4550	183	***
DL 5%	606			
DL 1%	824			
DL 0.1%	1103			

4. Conclusions

To increase the efficiency of organic fertilizers, very necessary on dumps, a compost was developed from manure, powdered lignite and potassium humates obtained by treating lignite with potassium hydroxide.

To find a new form of lignite exploitation and supply the deficit of organic fertilizers two fertilizers organo-mineral were produced: L_{200} and SH210, as well as four types of liquid fertilizers based on humates extracted from lignite with coexisting nitrogen as nitric, ammonia and amide and all the essential trace elements.

Research on Balta Unchiașului dump uncovered with fertile soil, focusing the influence of mineral, organic and organo-mineral fertilization on the maize, sunflower and peas yields led to the following conclusions:

1. The yields had large yearly differences due to climatic conditions and the land unevenness;
2. Very low yields were obtained in unfertilized variants;
3. All applied fertilizers ensured very significant yield increases;
4. For maize crop, compared to unfertilized variant, the different fertilizers ensured different yield increases as following: $N_{100}P_{80}K_{80}$ mineral fertilizers - 64%, the 40 t/ha manure fertilizers - 153%, the 40 t/ha compost - 156%, the organo-mineral fertilization (doses of 1000 l/ha) with L200 - 129% and with SH210 - 96%; while the increasing doses of organo-mineral fertilizer from 1000 to 1500 l/ha led to low yield increases;
5. Application of both mineral fertilizers and manure ensured a yield increase of 21%, while the application of mineral fertilizers and compost lead to an increase of 108%;
6. Application of compost with mineral fertilizers has ensured the highest yield increase, the yield level being similar to that obtained on neighbouring areas undisturbed by mining activities;

In the experiment on dump covered with 30-40 cm fertile soil, all four tested liquid fertilizers ensured very significant increases in maize yields, the yield level being similar to that obtained on nondegraded land areas.

References

Akala, V.A., Lal, R., 1999. Mineland reclamation and soil organic carbon sequestration in Ohio. ASSMR Proceedings 16th Annual National Meeting ”Mining and reclamation for the next millennium,, August 13-19 Scottsdale, Arizona.

Băbeanu, I.C., 1998. Cercetări privind proprietățile agrochimice ale haldelor de steril ale principalelor exploatări carbonifere la zi din Oltenia. Teză de doctorat, Universitatea din Craiova.

Bendfeldt, E.S., Burger, J.A., Daniels, W.L., Feldhake, C.M., 1999. Dynamics and characterization of soil organic matter in mine soils sixteen years after amendment with native soil, sawdust and sludge. ASSMR Proceedings 16th Annual National Meeting ”Mining and reclamation for the next millennium,, August 13-19 Scottsdale, Arizona.

Becherescu, C., Susinski, M., Dobre, M., Dascălu, D., Dodocioiu, A.M., 2008. Aspecte privind conţinutul real de humus al haldelor de steril rezultate în urma extracţiei cărbunelui la suprafaţă. Simpozionul Internaţional ”Reconstrucţia ecologică şi necesarul de îngrăşăminte în zona Gorjului”. 4-5 oct. 2007, Târgu Jiu, Editura NEW AGRIS - Reviste Agricole, Bucureşti.

Becheriţiu, M., 2003. Posibilități de cultivare a viței de vie pe haldele de steril, cu privire specială asupra producției și calității. Teză de doctorat, USAMV București.

Blaga, Gh., 1981. Cercetări pentru redarea în folosință agricolă a terenurilor degradate prin exploatări miniere în zona Căpuș - Aghireș. Teză de doctorat, Institutul Agronomic Timișoara.

Braia, M., 2004. Cercetări socio-economice privind valorificarea în pomicultură a haldelor de steril de la Rovinari-Gorj. Teză de doctorat, USAMV Bucureşti.

Călinoiu, M., 1999. Cercetări privind recultivarea terenurilor degradate datorită exploatărilor miniere la zi. Teză de doctorat, ASAS Bucureşti.

Cărăbiș, A.D., 2013. Reconstrucția ecologică a haldelor de steril". Teză de Doctorat, USAMV Bucureşti.

Cătinaș, I.C., 2012. Cercetări privind răspândirea, geneza și evoluția entiantrosolurilor (protosolurilor antropice) provenite de la exploatările miniere de suprafață din Nord Vestul Transilvaniei. Teză de doctorat, USAMV Cluj-Napoca.

Cioroianu, Tr.M., Sârbu, C., Dumitru, M., Dorneanu, A., Ştefănescu, D., 2009. Îngrăşăminte neconvenţionale - fertilizanţi lichizi. Ed. Estfalia, Bucureşti.

Clapa, D., 2003. Cercetări privind protosolurile antropice din Transilvania. Teză de doctorat, USAMV Cluj.

Craioveanu, Gh., Popescu, D., Carigoiu, V., Sârbu, L., 2002. Cercetări privind calitatea depozitelor geologice aduse la zi prin activități economice în bazinul minier Oltenia, pretabilitatea lor pentru activități productive. Comunicări Științifice ale simpozionului internațional „Reabilitarea terenurilor ocupate și afectate de activitatea de extracție a lignitului din bazinele miniere ale Olteniei„ 7-8 iunie, Târgu Jiu.

Chisăliță, I., 2001. Cercetări privind stabilizarea haldelor de steril de la Moldova Nou cu ajutorului vegetației forestiere si influenta acesteia asupra mediului. Teza de doctorat. Universitatea Transilvania, Brașov.

Călin, M.C., 2012. Cercetări privind reconstrucția terenurilor degradate din Podișul Transilvaniei prin stabilirea unor tehnologii de împădurire în contextul gospodăririi durabile. Teză de doctorat, USAMV Cluj Napoca.

Daniels, L.W., Stewart B., Dove D., 1995. Reclamation of Coal Refuse Disposal Areas. Virginia Cooperative Extension, Pub., 460-131.

Daniels, L.W., Schroeder, P.D., Nagle, S.M., Zelazny, L.W., Alley, M.M., 1999. Reclamation of prime farmland follewing mineral sands mining in Virginia. ASSMR Proceedings 16th Annual National Meeting"Mining and reclamation for the next millennium„ August 13-19 Scottsdale, Arizona.

Dinucă, C.N., 2015. Cercetări privind fundamentarea științifică a reconstrucției ecologice a haldelor de steril rezultate din exploatări miniere de suprafață din bazinul mijlociu al Jilțului și Motrului. Teză de Doctorat, Universitatea Transilvania din Brașov.

Dinucă, N.C., Târziu, D.R., 2015. Forest re-cultivation of sterile dumps as a result of lignite exploatation on daz. J.E.P.E., 16, No. 4, 1458-1467.

Dorneanu, A., Dorneanu, E., Sârbu, C., Cioroianu, Tr.M., Ilie, A., 2006. Utilizarea îngrăşămintelor lichide în contextul unei agriculturi moderne. Simpozionul Internaţional "Managementul nutrienţilor pentru îmbunătăţirea calităţii culturilor şi conservarea mediului". 13-14 iulie 2005, Craiova, Editura AGRIS.

Dorneanu, A., Preda, C., Dumitru, M., Huidu, E., Dorneanu, E., Bican, Sz., Cioroianu, T.M., Ştefănescu, D., Anton, I., Gheorghe, D., Prodan, T., 2008. Îngrăşăminte organominerale pe suport de lignit, mijloc important de fertilizare echilibrată a culturilor pe solurile cu conţinut redus de humus. Realizarea instalaţiei de producere la S.N.L.O Târgu Jiu. Simpozionul Internaţional "Reconstrucţia ecologică şi necesarul de îngrăşăminte în zona Gorjului". 4-5 oct. 2007, Târgu Jiu, Editura NEW AGRIS - Reviste Agricole, Bucureşti.

Eger, P., Melchert, G., Dewar, St., 1999. Waste for wastelands reclaiming tacomite tailings basins with organic amendments. ASSMR Proceedings 16th Annual National Meeting "Mining and reclamation for the next millennium„ August 13-19 Scottsdale, Arizona.

Eyheraguibel, B., Silvestre, J., Morard, P., 2008. Effects of humic substances derived from organic waste enhancement on the growth and mineral nutrition of maize. Bioresource Technology, Vol. 99, Issue 10, July 2008, 4206-4212.

Ianc, I., 1999. Evoluţia solului din bazinul carbonifer Rovinari în urma decopertării, reamenajării şi recultivării cu pomi şi viţă de vie. Teză de doctorat, ASAS, Bucureşti.

Munteanu, N., 1998. Cercetări privind cultivarea cu viţă de vie a terenurilor degradate prin exploatări miniere la zi din zona Rovinari - Gorj. Teză de doctorat, Universitatea din Craiova, Facultatea de Agricultură.

Negrea, C., 2007. Contribuţii la îmbunătăţirea sistemului român de bonitare a haldelor de steril din bazinul carbonifer Oltenia. Teză de doctorat, Universitatea din Craiova, Facultatea de Agricultură.

Oprea, V., 2010. Reconstrucția ecologică a terenurilor degradate din zona colinară a Transilvaniei prin cultura arbuștilor silvoamelioratori. Teză de doctorat, USAMV Cluj.

Pascovici, N.I., 2006. Impactul exploatărilor de lignit din bazinul Husnicioara - Mehedinți și posibilitatea de reconstrucție ecologică a habitatului natural. Teză de doctorat, Universitatea Politehnica din Timișoara, Facultatea de Hidrotehnică.

Popa, R.G., 2007. Cercetări privind efectul fertilizanţilor minerali şi organici asupra însuşirilor fizice şi chimice ale solurilor tehnogene din bazinul carbonifer Oltenia. Teză de doctorat, USAMV Bucureşti.

Preda, C., Dorneanu, A., Dumitru, M., Anton, I., Nicolaescu, I„ Huidu, E., Bican, Sz., 2008. Tehnologii de fabricare a fertilizanţilor organo-minerali pe bază de lignit. Simpozionul Internaţional "Reconstrucţia ecologică şi necesarul de îngrăşăminte în zona Gorjului". 4-5 oct. 2007, Târgu Jiu, Editura NEW AGRIS - Reviste Agricole, Bucureşti.

Roşculete, C.A., 2005. Folosirea unor fertilizanți organici de tipul composturilor în reconstrucția ecologică a haldelor de steril. Teză de doctorat, Universitatea din Craiova.

Sîrbu, C.E., Cioroianu, Tr.M., Dumitru, M., 2012. Fertilizanţi cu substanţe proteice. Ed. Sitech, Craiova.

Tatomir, C., Dumitru, M., Popescu, I., 2010. Impactul exploatării și utilizării asupra mediului. Ed. Sitech, Craiova.